GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 1

Contract Period: 10 June 1963 - 9 September 1963

Contract Number: NASr-192
Georgia Tech Project No. A-716

Contract Objective: Photographic, Photometric and Spectrographic Observations of Flames Generated at Altitudes Near 60 Miles

Contract Sponsor: National Aeronautics & Space Administration
Lewis Research Center
Cleveland, Ohio

Project Director: Howard D. Edwards

1. Investigations Being Undertaken

During the quarter, project personnel were engaged in the preparation of instruments to be taken to Valley Forge, Pennsylvania to observe a ground test of the flames of chlorine trifluoride with benzene and acetonitrile.

The trip to Valley Forge was made between September 4-7. Two spectrographs and two 35 mm Mod IV cameras were used in the observations.

The Mod IV cameras were equipped with 10 inch lenses and operated at 20 fps using RXP film. Exposure time was approximately 1/120 sec. One camera was stopped down to approximately f/100 by means of a small hole in the lens cap. The other was operating at f/22 and had Wratten filters No. 47 and 0.3 N.D. in front of the lens.

A spectrograph built into a K-46 camera was operated without slit and was equipped with an f/1.2 50 mm lens and a 600 groove/mm transmission grating. The film was moving continuously at about 9 inches/sec to give time resolution for the spectra. The second spectrograph had a fixed slit and used a 600 groove/mm reflection grating, 35 mm film and f/1.8 camera lens. The unit was hand operated and as many spectra as possible were taken during the few seconds that the flame lasted.

2. Plans for Next Period

Reduce data from Valley Forge ground tests and prepare for rocket firings at Wallops Island, Virginia, scheduled during the next quarter.

3. Travel - Hodgdon, Cooksey, Edwards to Valley Forge, Pennsylvania September 4-7, 1963.

4. Fiscal Information - The estimated unencumbered balance remaining on 31 August 1963 was $16,500.

Submitted by:

Howard D. Edwards
Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 2

Contract Period: 10 September 1963 - 9 December 1963

Contract Number: NASr-192
Georgia Tech Project No. A-716

Contract Objective: Photographic, Photometric and Spectrographic Observations of Flames Generated at Altitudes Near 60 Miles

Contract Sponsor: National Aeronautics & Space Administration
Lewis Research Center
Cleveland, Ohio

Project Director: Howard D. Edwards

1. Investigations Being Undertaken

Good spectra and photographs were obtained by the 35 mm spectrograph and Mod IV cameras respectively for both flames (i.e. chlorine trifluoride with benzene and with acetenitrile) during the Valley Forge ground tests. Data resulting from the analyses of these films are being used for comparison with data obtained from the high altitude releases which took place at Wallops Island, Virginia on 9-10 October 1963.

Project personnel participated in the rocket firings at Wallops Island and established observing stations at Virginia Beach, Virginia (Dam Neck Marine Base), Wallops Station (Bldg. N159), and Camp A. P. Hill, Virginia. Each station was equipped with two or more K-24 cameras for triangulation photography in the visible and infrared regions, and with one or more slitless spectrographs to obtain spectral characteristics. Slit type spectrographs were operated at building N-159 and at Dam Neck. Two small 35 mm units covering the visible and infrared regions were at N-159 and an auroral type with f/0.8 Schmidt type camera lens was at Dam Neck. In addition, two Mod IV 35 mm cameras operating at 20 fps and an ultraviolet telescope with image converter tube to "look at" the region 3000-4000 Å were in operation at building N-159.

Good data were obtained on most of the instruments for both of the flames and are in the process of being reduced. As various pieces of data are reduced they are sent to Dr. A. Potter for study and integration with the analyses which he and his colleagues are doing.

2. Plans for Next Period

Continue analysis of data from the October 9-10 rocket firings.

3. Travel - Seven project personnel participated in the field operations October 5-12, 1963 at Wallops Island, Virginia.

4. Fiscal Information - The estimated unencumbered balance remaining on 31 October 1963 was $9,600.

Submitted by:

H. D. Edwards
Project Director

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GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 3

Contract Period: 10 December 1963 - 9 March 1964

Contract Number: NASr-192
Georgia Tech Project No. A-716

Contract Objective: Photographic, Photometric and Spectrographic Observations of Flames Generated at Altitudes Near 60 Miles

Contract Sponsor: National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

Project Director: Howard D. Edwards

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1. Investigations Being Undertaken

Studies made during the latter part of last quarter on the spectrograms taken of the high altitude releases on 9-10 October were not very satisfactory due primarily to the short duration of the luminous cloud and low sensitivity of film spectrographs.

On December 6, 1963 the film was mailed to Dr. Potter for further study. Considerable progress was made in determining intensity and spectral band identifications. However, further work needs to be done and upon return of the film to Georgia Tech during March, further studies will be made by means of a new microdensitometer installed during February.

Triangulation photographs taken of the clouds gave good position determinations for the trails and are listed in table 1.

1st Release, 9 October 1963, 6:14 PM EST

T + Time (Sec)	Height (km)	Latitude (Deg. N)	Longitude (Deg. W)
180	155.4	37.196	75.023
181	155.8	37.191	75.019
182	156.0	37.187	75.016
183	156.0	37.188	75.017
185	156.4	37.177	75.009
186	156.5	37.174	75.007
187	156.7	37.170	75.004
194	157.4	37.143	74.986
195	157.4	37.137	74.982
196	157.6	37.134	74.980
197	157.6	37.130	74.977
198	157.5	37.127	74.978
200	157.7	37.119	74.970

2nd Release, 10 October 1963, 6:13 PM EST

T + Time (Sec)	Height (km)	Latitude (Deg. N)	Longitude (Deg. W)
180	155.0	37.871	74.614
183	155.3	37.871	74.605
186	155.6	37.871	74.590
187	155.9	37.871	74.582
195	156.2	37.872	74.559

2. Plans for Next Period

Continue analysis of spectral data from the October 9-10 rocket firings and in particular with the new microdensitometer.

3. Fiscal Information: The estimated unencumbered balance remaining on 29 February 1964 was $5,800.

Submitted by:

H. D. Edwards
Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 4

Contract Period: 10 March 1964 - 9 June 1964

Contract Number: NASr-192
Georgia Tech Project No. A-716

Contract Objective: Photographic, Photometric and Spectrographic Observations of Flames Generated at Altitudes Near 60 Miles

Contract Sponsor: National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

Project Director: Howard D. Edwards

1. Investigations Being Undertaken

Further studies have been made on both the Mod IV films from the Elverson tests and the spectra from Lou.

The Mod IV films from the Elverson tests have been densitometered and calculations of total intensity have been performed. Comparison was made with a sensitometric strip placed on the film after returning to Georgia Tech, and the density on the film from both tests exceeded the maximum density of the sensitometric strip. Extrapolation of the H and D curve was necessary to determine the energy falling on the film. Considering the lens transmissions, f-stops, the no. 47 filter transmission, and the approximate spectral distribution of the incident light, the visual intensities of both acetonitrile and benzene are:

Total: approx. 0.8 watts/cm^2

Passing No. 47 filter: approx. 0.06 watts/cm^2 - Å

The above values may vary by as much as a factor of 5 due primarily to the over exposure. In spite of the uncertainty in absolute intensity the benzene release was slightly less intense than the acetonitrile.

Considering the spectra on Lou, the aurora spectrogram was densitometered, and background spectra was subtracted at approximately 10 Å intervals. Grain measurements were also made and entered into the calculations as to the probability of a "band" being a true band or just grain. Examining the release of Lou, we agree with your results on the following:

CN (3586-3590)
CN (3883-3910)
CN (4181)
CH (4312)

We do not find the band of CN at 4654 and wonder if this is not grain.

The spectrum seems to have a slight continuum superimposed on the N_2 spectra from the second positive system.

We agree that C_2 is probably not present. However, a possibility exists for C_3 (4505) since both the Lewis and Georgia Tech densitometers revealed a band or line structure at 4518, which is unidentified:

A comparison of the bands from the Lewis and Georgia Tech results are as follows:

Lewis*	Georgia Tech**	Assignment
3530	3550	2nd pos. N_2 (3537)
3585	3587	CN (3586)
3623	3625	possibly grain
3695	3705	2nd pos. N_2 (3710)
3903	3896 (broad)	CN (3883)
3950	3953	2nd pos. N_2 (3943)
4017	4009	2nd pos. N_2 (3998)
4052	4061	2nd pos. N_2 (4059)
4101	4102	
4177	4174	CN (4181)
4225	4199 (diffuse)	2nd pos. N_2 (4200)
4261	4271	2nd pos. N_2 (4270)
4308	4308	CH (4312)
4399	4418 (broad)	2nd pos. N_2 (4417)
4518	4518	C_3 (4505) ?
4590	4597	
4868	4868	

* Wavelength values obtained from the densitometer traces which you sent.

** Wavelength values from Georgia Tech densitometer traces.

A comparison has been made between the Mary K-24 film and the photographs taken of the 40 lbs of water which was released over Wallops in March 1962.

The water release persisted for approximately two minutes, whereas the Mary film shows no appreciable persistence. The Mary photographs show a bright core with fuzz around it. However, the fuzz does not persist after the bright center has disappeared. Hence, we see nothing that we would consider as solid particles which are traveling the ballistic trajectory.

2. Plans for Next Period

Efforts to extract additional meaningful data from the two rocket firings will be continued.

3. Fiscal Information The estimated unencumbered balance remaining on 9 June 1964 was $4,500.

Submitted by:

H. D. Edwards
Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 6

Contract Period: 10 September 1964 - 9 December 1964

Contract Number: NASr-192
Georgia Tech Project No. A-716

Contract Objective: Photographic, Photometric and Spectrographic Observations of Flames Generated at Altitudes Near 60 Miles

Contract Sponsor: National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

Project Director: Howard D. Edwards

1. Investigations Being Undertaken

No further work was carried out during the quarter on film from the rocket firings which took place on 9-10 October 1963.

A small amount of project funds were expended in improving and maintaining instrumentation to be used on possible future field trips.

2. Plans for Next Period

After consultation with Dr. Potter no further work is planned under this contract and the contract will terminate on 31 December 1964.

3. Fiscal Information

The estimated unencumbered balance remaining on 9 December 1964 was $2,200.

Submitted by:

Howard D. Edwards
Project Director

PHOTOGRAPHIC, PHOTOMETRIC AND SPECTROGRAPHIC OBSERVATIONS OF FLAMES GENERATED AT ALTITUDES NEAR 60 MILES

by Howard D. Edwards

FINAL REPORT

Georgia Tech Project A-716

Prepared for and Sponsored by
Chemical and Energy Conversion Division
Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio

Contract NASR-192

1965

January 1965

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

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PHOTOGRAPHIC, PHOTOMETRIC AND SPECTROGRAPHIC OBSERVATIONS OF FLAMES GENERATED AT ALTITUDES NEAR 60 MILES

by
Howard D. Edwards

FINAL REPORT

Georgia Tech Project A-716

Prepared for and Sponsored by
Chemical and Energy Conversion Division
Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio

Contract NASR-192

January 1965

Abstract

Contract NASR-192 with the Lewis Research Center of NASA was initiated on June 10, 1963 and terminated on December 31, 1964.

The objective of the contract was:

> "Photographic, Photometric and Spectrographic Observations of Flames Generated at Altitudes Near 60 Miles"

In particular, two flames were studied. The first was a mixture of chlorine trifluoride with benzene and the second a mixture of chlorine trifluoride with acetonitrile. A series of ground tests on the flames were held at Valley Forge, Pennsylvania, during the period September 4-7, 1963. Rocket flights took place on October 9-10, 1963, in which the flames were produced in the vicinity of 90 miles altitude.

This report is primarily a summary of the results which were obtained from observations made on the flames and the equipment which was used in obtaining the data.

and the other was operated at f/22 and had Wratten filters No. 47 and 0.3 N.D. in front of the lens.

Two spectrographs were used to observe the flames. One spectrograph was built into a K-46 camera body. The spectrograph was operated without a slit and was equipped with an f/1.2 lens of 50 mm focal length and a 600 groove/mm transmission grating. The film was moving continuously at about 23 cm/sec to give time resolution for the spectra. The second spectrograph had a fixed slit and used a 600 groove/mm reflection grating, 35 mm film and f/1.8 camera lens. This unit was hand operated and as many spectra as possible were taken during the few seconds lifetime of the flame.

Results Obtained From Ground Tests Good spectra were obtained from the fixed slit 35 mm spectrograph for both flames but no data were obtained from the moving film spectrograph.

The Mod IV films from the Elverson tests were densitometered and total intensity calculated. Comparison was made with a sensitometric strip placed on the film after returning to Georgia Tech, and the density on the film from both tests exceeded the maximum density of the sensitometric strip. Extrapolation of the H and D curve was necessary to determine the energy falling on the film. Considering the lens transmissions, f-stops, the No. 47 filter transmission, and the approximate spectral distribution of the incident light, the total visual intensity of both acetonitrile and benzene was approximately 0.8 watts/cm^2 and the intensity passing through the No. 47 filter was approximately 0.06 watts/cm^2 - Å. The above values may vary by a factor of 5 due primarily to the over exposure. In spite of the uncertainty in absolute intensity the benzene release was slightly less intense than the acetonitrile.

Rocket Flights at Wallops Island, Va.

Rocket Borne Apparatus Two Nike-Apache vehicles were launched at 6:14 p.m. EST and 6:13 p.m. EST on 9 October 1963 and 10 October 1963 respectively.

The vehicle on 9 October carried a payload of chlorine trifluoride and acetonitrile and the vehicle on 10 October carried a payload of chlorine trifluoride and benzene. The payload in each case was 90 lbs. and the rocket was theoretically capable of reaching an altitude of 100 miles.

The flame generator, which comprised the total payload, consisted of a chlorine trifluoride tank containing about 15 lbs. of ClF_3, a fuel tank containing about 8 pounds of benzene or acetonitrile, and two opposed combustion chambers. The fuel and oxidizer were pressurized under about 750 psi of Argon, and were admitted to the combustion chambers upon the opening of two squib-actuated valves. The fuel and oxidizer combination were hypergolic, so that no igniter was necessary.

Ground Based Apparatus Observing stations were established at Virginia Beach, Virginia (Dam Neck Marine Base), Wallops Station (Bldg. N159), and Camp A. P. Hill, Virginia. Each station was equipped with two or more K-24 cameras for triangulation photography in the visible and infrared regions, and with one or more slitless spectrographs to obtain spectral characteristics. Slit type spectrographs were operated at building N159 and at Dam Neck. Two small 35 mm units covering the visible and infrared regions were at N159 and an auroral type with f/0.8 Schmidt type camera lens was at Dam Neck. In addition, two Mod IV 35 mm cameras operating at 20 fps and an ultraviolet telescope with image converter tube to "look at" the region 3000-4000 Å were in operation at building N159.

Results Obtained From Rocket Flights Triangulation photographs taken of the clouds gave good position determinations for the trails and are given in table 1.

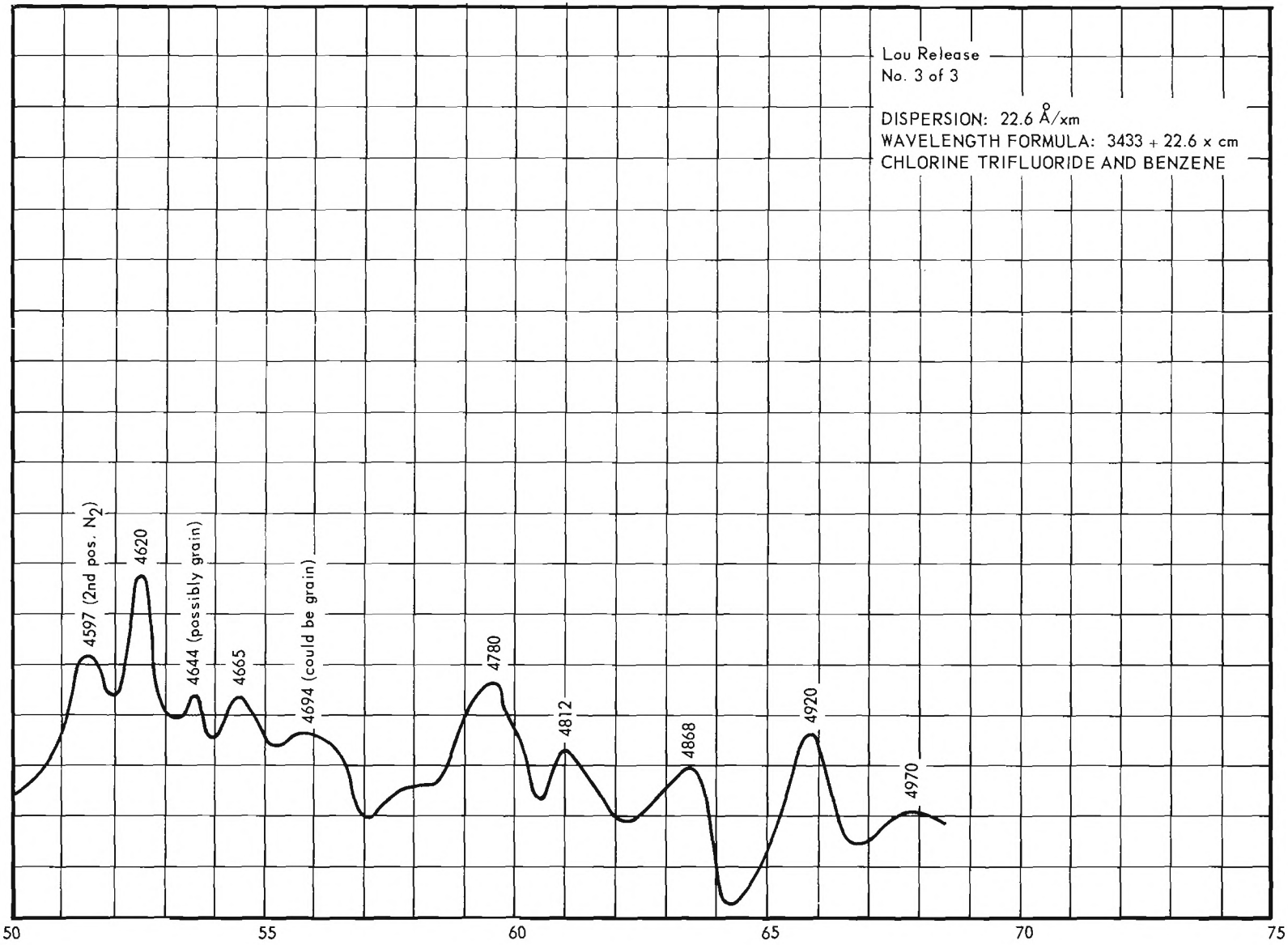

Figure 1 (Continued).

References

1. Richter, N. B., The Nature of Comets, 178-192, Methuen (1963)

2. Skirrow, G. and Wolfhard, H. G., Studies of Chlorine Trifluoride Flames, Proc. Royal Soc., Vol. 232 A, 78-87, 1955

3. Edwards, H. D., Optical Observation of a High Altitude Release of Water Over Wallops Island, Va. on March 2, 1962, Technical Report No. 1, Contract NAS1-1671, March 1962